Comparative Effectiveness of Three Techniques for Salamander and Gastropod Land Surveys

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Abstract.—We compared the effectiveness and efficiency of three terrestrial salamander and gastropod trapping techniques: pitfall traps, ground searches and cover boards. The study was conducted on 18 stands with three management histories in the Umpqua National Forest, southern Oregon Cascades. A total of 648 pitfall traps were open for 28 consecutive days in fall 1999. Two hundred twelve amphibians (eight species) and 202 gastropods (six species) were captured. Also in fall 1999, 36 h of ground searches covering 3600 m² resulted in the detection of 19 amphibians (two species) and 130 gastropods (six species). Four cover boards (100×100 cm) in stacks of two were placed in each stand and checked four times in fall 1999 and once in spring 2000 after snow melt. Cover boards concealed no amphibians and only two gastropods (one species). Pitfall traps were more efficient at capturing amphibians than ground searches (0.41 vs. 0.25 captures per hour of effort), but less efficient at capturing gastropods than ground searches (0.39 vs. 1.73 captures per hour of effort). Cover boards as used were ineffective at capturing either amphibians or gastropods. Climatic conditions of the southern Oregon Cascades likely influenced the results.

Introduction

In the Pacific Northwest, two methods commonly are used to sample terrestrial salamanders: pitfall trapping and ground searches. Cover boards, a third sampling method, have been used sparingly in the Northwest, despite their success in the eastern United States (DeGraaf and Yamasaki, 1992; Harpole and Haas, 1999; Monti *et al.*, 2000; Hyde and Simons, 2001; Jaeger *et al.*, 2001).

There are many pitfall trap variations, but generally a pitfall consists of a deep depression in the ground that entraps animals that fall into it and restricts their escape. Pitfall traps have been used to estimate the seasonal activity, reproductive status and abundance of species (*e.g.*, Campbell and Christman, 1982; Corn and Bury, 1990). There is evidence, however, that estimates of salamander abundance derived from pitfall trapping are biased (Corn and Bury, 1991; Heyer *et al.*, 1994, p. 75–141). Sub-surface activity, arboreal junkets (*see* Nussbaum *et al.*, 1983, p. 11–25) and sedentary behavior all decrease the probability of capture. Consequently, trappability differs widely among species (Campbell and Christman, 1982; Bury and Corn, 1987; Corn and Bury, 1990).

Ground searches entail actively probing for salamanders on the forest floor within a defined area (area-constrained search), over a defined time period (time-constrained search) or a combination of both (time- and area-constrained search) (Welsh, 1987; Corn and Bury, 1990; Heyer *et al.*, 1994, p. 75–109). Searches are performed during the night or day and vary in intensity from "low" to "high" depending on the amount of forest floor disruption (Heyer *et al.*, 1994, p. 84–92). Ground searches provide information on salamander presence/absence and microhabitat use and they commonly are used for inventory purposes, *e.g.*, as directed in the Survey and Management Provision of the

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Northwest Forest Plan (Corn and Bury, 1990; Olson, 1999). Similar to pitfall trapping, however, ground searches are inappropriate for abundance estimation because of possible search bias (Corn and Bury, 1990). Not only are salamanders difficult to detect in structurally complex environments, but detection efficiencies also may differ among investigators.

Cover boards are wooden boards of various dimensions that are placed on the forest floor to simulate natural down wood. Several studies have effectively used cover boards to capture salamanders (DeGraaf and Yamasaki, 1992; Davis, 1998; Harpole and Haas, 1999; Monti *et al.*, 2000; Hyde and Simons, 2001; Jaeger *et al.*, 2001). Because boards can be checked repeatedly without forest floor disruption and they require less effort to search than many natural forest floor objects, they have been proposed for long-term monitoring of terrestrial amphibian populations (Jung *et al.*, 2000; Hyde and Simons, 2001).

In 1994 the Northwest Forest Plan Survey and Management Standards and Guidelines (U.S.D.A. and U.S.D.I., 1994, Table C-3) listed 43 snails and slugs as Species of Concern. Consequently, a unique gastropod search procedure was developed (U.S.D.A. and U.S.D.I., 1997). In this technique, brief searches are made of solitary or ubiquitous habitat structures (e.g., a piece of down wood or leaf litter, respectively) in a 10-m wide strip; intensive searches are made of habitat clusters (e.g., a down wood pile). This survey method was designed to assess the presence or absence of target species, not to estimate abundance or evaluate habitat use. A second gastropod survey technique involves the identification of animals released from soil cores immersed in hot water. This method is useful for population estimation and to investigate habitat use; but it results in mortalities, is time intensive and is biased toward small litter-dwelling gastropods (Mason, 1970).

Because gastropods often occupy habitats used by terrestrial salamanders, snails and slugs frequently are encountered during salamander surveys (McDade, 2002). It is desirable, then, to have information on the effectiveness (*i.e.*, the quantity and quality of data provided) and efficiency (*i.e.*, results obtained per unit effort) of various sampling methodologies in regards to both animal groups. To meet this objective, we compared the efficacy of pitfall traps, time- and area-constrained searches and cover boards for capturing both salamanders and gastropods in forest environments.

STUDY AREA AND METHODS

Our study was conducted in the Umpqua National Forest, Oregon (Douglas County, 43°15′N latitude, 122°30′W longitude) in the Mixed-Conifer Zone (Franklin and Dyrness, 1988) (Fig. 1). Clearcut, commercial thin and uncut stands >135-y old, were selected in each of six blocks for a total of 18 stands (Table 1). Clearcut and thinned stands were harvested 5–11 y and 10–16 y before data collection, respectively. Clearcut and thinned stands ranged from 93–256 y old at harvest. The forest overstory was dominated by Douglas-fir (*Pseudotsuga menziesii*), but also contained sugar pine (*Pinus lambertiana*), ponderosa pine (*P. ponderosa*), incense-cedar (*Calocedrus decurrens*) and white fir (*Abies concolor*) (Franklin and Dyrness, 1988; Chappell *et al.*, 2001). Understory vegetation contained manzanita (*Arctostaphylos* spp.), Oregon-grape (*Berberis* spp.), salal (*Gaultheria shallon*), Pacific rhododendron (*Rhododendron macrophyllum*), beaked hazel (*Corylus cornuta*), vine maple (*Acer circinatum*), trailing blackberry (*Rubus ursinus*), ceonothus (*Ceonothus* spp.) and bracken fern (*Pteridium aquilinum*). Elevations of stands range from 790–1200 m and slopes are between 0–60%.

Pitfall traps were arrayed in a 6×6 grid with 10-m spacing between gridpoints (Fig. 2); grids were randomly located in the interior of each stand. All grids were oriented upslope and were at least 20 m from roads, other stands and water. Traps were constructed of two

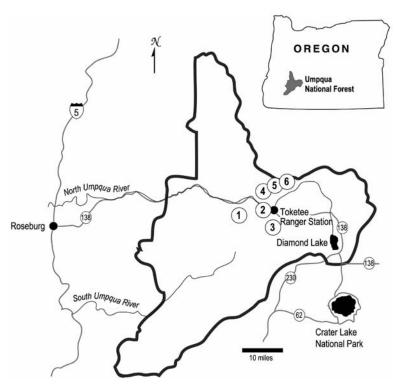


Fig. 1.—Locations of six study blocks (represented by numbered circles) each comprised of clearcut, commercial thin and uncut silvicultural treatments in the Umpqua National Forest, southern Oregon Cascades

10 metal cans joined together with duct tape, creating a cylinder with a solid bottom and open top. Joined cans were placed in the ground with the top rim flush with the forest floor (Corn and Bury, 1990). A plastic funnel, made from a 1-lb (373-g) margarine tub with the bottom removed, was placed on the trap opening to restrict animal escapes. Natural materials (e.g., wood, moss) were added to each pitfall to shelter captured animals and holes were punctured in the bottom to drain rainfall and surface runoff. Traps were placed within 2 m of each grid point (Fig. 2) adjacent to a natural drift fence, such as a log. Pitfall traps were operated for 28 consecutive days in each stand and checked once daily during fall 1999 after commencement of the rainy season. Traps in blocks 1, 2 and 3 were open from 23 October to 19 November and traps in blocks 4, 5 and 6 were open from 20 October to 16 November. Captured salamanders were identified to species, weighed, measured (total length and snoutvent lengths) and sexed when possible; gastropods were identified at least to genus. Captured animals were released between trapping stations near a suitable cover object.

Time- and area-constrained ground searches of intermediate intensity were performed spring and fall 1999 during daylight hours on parallel $50-\times 1$ -m strip transects positioned perpendicular to the contour on each sampling grid (Fig. 2). Salamanders, snails and slugs were located by hand searching through bark piles, down wood, litter and other forest floor objects within each transect (Corn and Bury, 1990). "Moving rules" were applied (Olson, 1999) such that no single object was searched longer than 5 min and total search time was

TABLE 1.—Mean stand characteristics of three silvicultural treatments in mixed-conifer forest in the Umpqua National Forest, Oregon. Each silvicultural treatment had six stand replicates. Dead wood (snags and down wood) decay classes are sound wood (decay class 1), moderate decay (decay class 2) and heavy decay (decay class 3)

	Clearcut		Commerical thin		Uncut	
Stand variables	Mean	SE	Mean	SE	Mean	SE
General characteristics						
Age at harvest (y)	183.4	32.93	161.0	68.00	N/A	_
Age since harvest/disturbance (y)	7.5	0.85	12.5	0.92	202.8	18.83
Stand size (ha)	13.1	2.32	17.2	7.44	19.3	5.00
Elevation (m)	1021.1	36.70	1016.0	44.29	1071.9	48.14
Slope (%)	24.6	6.08	22.3	5.34	26.6	4.94
Aspect (0–1)	0.5	0.14	0.6	0.16	0.5	0.12
Live trees (>5 cm dbh)						
Basal area (m²/ha)	0.1	0.05	31.1	1.75	61.7	4.70
Number of trees (#/ha)	26.6	14.73	192.0	44.55	595.9	98.58
dbh (cm)	0.1	0.07	75.6	7.17	81.6	4.64
Canopy cover (%)	1.0	0.57	67.3	2.61	88.5	1.03
Understory						
Shrub cover (%)	10.1	0.64	20.8	6.47	16.9	5.03
Herb cover (%)	70.4	3.17	59.3	5.50	50.8	6.60
Snags						
Basal area (m²/ha)	0.8	0.38	3.3	0.74	9.4	2.31
Number of trees (#/ha)	21.2	12.49	54.0	19.97	157.3	40.13
Decay class (1–3)	1.8	0.48	1.6	0.10	2.4	0.17
Volume (m³/ha)	1.2	1.10	21.7	10.82	73.6	55.10
Down wood						
Total volume (m ³ /ha)	153.5	41.50	178.0	34.01	189.4	27.49
Decay class 1 volume (m ³ /ha)	32.7	18.13	74.2	22.49	40.6	20.28
Decay class 2 volume (m ³ /ha)	71.7	17.27	35.7	8.11	27.9	6.06
Decay class 3 volume (m ³ /ha)	49.0	16.39	68.1	24.11	120.8	25.58
Decay class (1–3)	2.1	0.10	2.1	0.10	2.2	0.09
Diameter (cm)	11.7	0.64	14.6	1.39	16.1	1.09
Length (m)	252.0	38.59	611.6	125.61	816.3	88.16
Cover (%)	0.1	0.02	0.1	0.01	0.1	0.01
Forest floor						
Duff and litter depth (cm)	4.6	1.19	5.2	0.81	7.4	0.99

30 min of effort per transect. Spring sampling was truncated due to unusually hot and dry conditions and only 5.5% of transects were searched (n = 7 transects; 350 m^2). Fall sampling was more productive, still only four of the seven transects per stand were surveyed (57.1%) due to freezing temperatures and snow (n = 72 transects; 3600 m^2). Data recorded for salamanders and gastropods encountered during ground searches were identical to that described under pitfall sampling. All animals were released in the vicinity of capture.

Cover boards measuring $1 \times 100 \times 100$ cm were placed in two stacks of two boards adjacent to each pitfall grid (Fig. 2). The boards were reclaimed Masonite particle board bonded with nontoxic blood meal glue. Small pieces of wood found on site were inserted

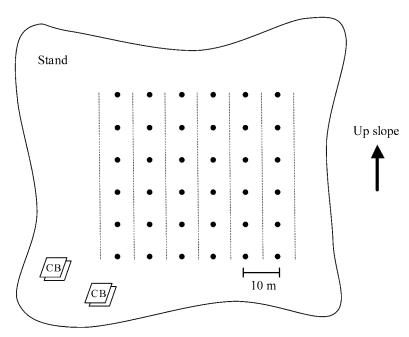


Fig. 2.—Schematic of sample grid and data collection locations on each stand. Solid circles represent grid points where pitfall traps were installed, dotted lines are strip transect ground search locations and 'CB' designates cover board locations

beneath and between the stacked boards to create animal entry gaps approximately 2-cm wide. Cover boards were placed by 23 October 1999 and checked once per week during the pitfall trapping session for a total of four fall samples per stand. Cover boards were left in place over winter and rechecked after snow melt on 24 May 2000.

Weather data were recorded using weatherproof data collectors (Onset HOBO®) and plastic rain gauges. Six data collectors were distributed among each of the three treatments in blocks 2 and 5 (Fig. 1). Block 5 contained the highest elevation stands, whereas block 2 contained the lowest. Data collectors were placed 15 cm above ground on the outside edge of the sampling grid of the selected stands. Temperature and relative humidity were recorded continuously at 15-min intervals from spring through fall 1999. One rain gauge was placed in an open area within each of the 18 study stands and rain data were collected once daily during the fall 1999 trapping session. Spring and summer 1999 rain data were collected bimonthly.

RESULTS AND DISCUSSION

Because both salamanders and gastropods are sensitive to temperature and moisture extremes (Littleford *et al.*, 1947; Machin, 1975) sampling in the Pacific Northwest usually is conducted in spring and fall when weather is cool and moist. During the 28-d fall sampling period, pitfall traps captured 202 salamanders representing five species and 202 gastropods representing six species/species groups (Table 2). It took approximately 10 h of effort to install each pitfall grid; if drift fences were included, it is estimated that the installation time would have doubled (Corn and Bury, 1990). One benefit of pitfall trapping is that once traps

TABLE 2.—Number of amphibians and gastropods captured fall 1999 using three capture techniques: pitfall traps, ground searches and cover boards. Sampling intensity varied among treatments; see text

Species/individuals	Pitfall	Search	Cover board	Total
Amphibian total	212	19	0	231
Salamanders				
Ensatina ^t (Ensatina eschscholtzii)	156	18	0	174
Northwestern salamander ^p (Ambystoma gracile)	20	0	0	20
Rough-skinned newt ^p (Taricha granulosa)	16	0	0	16
Clouded salamander ^t (Aneides ferreus)	9	1	0	10
Pacific giant salamander ^s (Dicamptodon tenebrosus)	1	0	0	1
Frogs				
Pacific treefrog ^P (Pseudacris regilla)	7	0	0	7
Cascades frog ^P (Rana cascadae)	2	0	0	2
Tailed frog ^s (Ascaphus truei)	1	0	0	1
Gastropod total		130	2	334
Snails				
Haplotrema spp.	127	70	0	197
Vespericola spp.	33	41	2	76
Pacific sideband (Monadenia fidelis fidelis)	0	4	0	4
Ancotrema spp.	1	1	0	2
Slugs				
Reticulated tail dropper (Prophysaon andersoni)	23	9	0	32
Banana slug (Ariolimax columbianus)		0	0	15
Blue-gray tail dropper (Prophysaon coeruleum)	3	5	0	8

^t terrestrial breeder; ^p pond breeder; ^s stream breeder

are installed, a large geographic area can be sampled simultaneously with minimal personnel. In our study, it took approximately 12 h of effort to check the 648 traps each day.

Pitfall traps captured salamanders, snails and slugs at rates of one animal per 2.6, 3.2 and 12.5 h of effort, respectively, or 0.39, 0.31 and 0.08 animal for each hour of effort (Table 3). These capture rates are considerably lower than those found by Welsh (1987), who captured 3.2 salamanders per hour of effort in old, mixed conifer-hardwood forests in northwestern California and southwestern Oregon. In our study, there were 18,144 trap-nights (648 pitfall traps × 28 d) resulting in a trap success rate of 1.17 salamanders per 100 trap-nights (Table 3). This capture rate is somewhat lower than for studies conducted in managed and unmanaged stands in the Oregon and Washington Cascades (Bury and Corn, 1988) and in the Oregon Coast Range (Corn and Bury, 1991) where 1.77 and 1.29 salamanders was captured per 100 trap-nights, respectively. To our knowledge, comparative results for pitfall trapping of gastropods are lacking.

Pitfall traps successfully captured salamanders and snails presumably because animals entered traps during the night when weather conditions were most favorable (Fig. 3), and they remained during the day in the relatively cool moist environments provided by the traps. Due to the mortality concerns associated with the capture of non-target small mammals (Aubry and Stringer, 2000; Perkins and Hunter, 2002), some researchers propose that pitfalls are best suited for research and they do not recommend them for inventory and monitoring purposes (Olson *et al.*, 1997).

TABLE 3.—Number of captured animals based on the time required to set up and perform three different trapping methods as conducted following the protocols of this study

Capture technique	No. of captures	No. of species	Total effort- hours	Captures per effort-hour	Species per effort-hour	Captures per 100 trap nights
Pitfall traps ¹						
Amphibians	212	8	516	0.41	0.02	1.17
Salamanders	202	5	516	0.39	0.01	1.11
Frogs	10	3	516	0.02	0.01	0.06
Gastropods	202	6	516	0.39	0.01	1.11
Snails	161	3	516	0.31	0.01	0.89
Slugs	41	3	516	0.08	0.01	0.23
Ground searches ²						
Amphibians						
Salamanders	19	2	75	0.25	0.03	0.10
Gastropods	130	6	75	1.73	0.08	0.72
Snails	116	4	75	1.55	0.05	0.64
Slugs	14	2	75	0.19	0.03	0.08
Cover boards ³						
Gastropods						
Snails	2	1	36	0.06	0.03	0.01

¹ Pitfall traps required 180 h to set up and 336 h to monitor and maintain

Winter 1998–1999 was characterized by an unusually heavy and late snowfall. Consequently, spring ground searches did not begin until 20 May when stands became snow-free. Daily searches lasted only one week and many of those searches were truncated when weather conditions rapidly became hot and dry. By late morning on a typical day, ambient relative humidity fell below the 45–65% minimum associated with above ground salamander activity (Fig. 3) (Olson, 1999), and soil conditions beneath litter, down wood and rock were often dry. As a result, spring ground searches consisted of only 3.5 h of search time (350 m² searched) and revealed only one salamander.

Fall 1999 ground searches were more productive than spring searches, but weather remained a complicating factor. Consistent fall rains, favorable for above ground salamander activity, did not commence until 26 October. Despite heavy rains in late October, it took longer than 1 wk for the ground to become moist in the top few centimeters of the forest floor and underneath common habitat structures (e.g., down wood). By 17 November minimum temperatures were dropping below 4 C, conditions considered too cold for sampling terrestrial salamanders (Fig. 4) (Olson, 1999). One advantage of ground searches is that they can be performed without preparation and, therefore, can take advantage of optimal weather conditions when they occur.

Although ground searches required no plot installation time, it took a total of 103 h to search all 72 transects (35 m²/hour of effort). This included time to identify, measure and record encountered animals in addition to the 30 min of search time allotted per transect. Thus, only a small proportion of transects could be sampled per person per day. Additionally, because captures often correlate with weather, conclusions drawn from capture comparisons between sites surveyed on different days may be confounded by variable weather conditions.

² Ground searches required no set up time but 75 h to monitor and maintain

³ Cover boards required 6 h to set up and 30 h to monitor and maintain

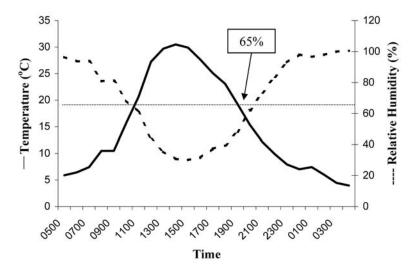


Fig. 3.—Clearcut stand temperature and percent relative humidity on 27 May 1999. This figure represents weather conditions on a typical day during the spring ground search session. By 1100 h relative humidity fell below 65%, creating above ground conditions inhospitable for salamanders (Littleford *et al.*, 1947) and gastropods (Machin, 1975)

Ground searches were more effective than pitfall traps at capturing gastropods, especially snails. On average, one snail was found every 39 min of search time (1.5 snails/hour of effort; 0.03 snail/m^2) (Table 3). Comparatively, it took 5.3 h to capture one slug (0.2 slug/hour of effort; 0.004 slug/m^2). The low number of slug encounters may be attributed to several possibilities: (1) slugs may not be abundant in the forest systems studied, (2) slugs

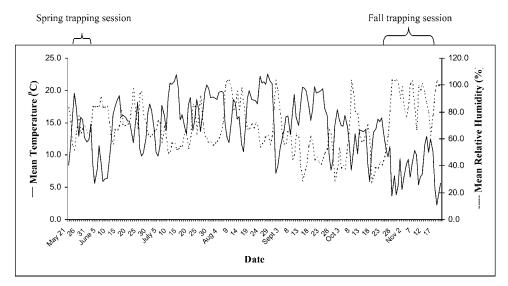


Fig. 4.—Mean daily temperature and percent relative humidity from 21 May through 19 November 1999 averaged across the 18 study stands in Umpqua National Forest, Oregon

may be difficult to detect when surface conditions are structurally complex and (3) because slugs lack shells and are more susceptible to desiccation than shelled gastropods (South, 1992), they may reside within the soil column during dry periods and go undetected in ground surveys.

In this study, ground searches were less effective for detecting salamanders than gastropods. Only two of five salamander species encountered during the study were represented in ground searches (Table 2), and frogs were never detected by this technique. Salamanders were hand captured at a rate of one per four search hours or 0.3 salamander per hour of effort (0.005 salamander/m²) (Table 3). In contrast, using time-constrained searches in Oregon and Washington, Bury and Corn (1988) captured 1.7 salamanders and 0.8 salamander per hour of effort, respectively, and Welsh (1987) captured 5.0 salamanders per hour of effort. It is difficult to determine whether these encounter differences are due to variation in population sizes or to variation in the effectiveness of ground searches across variable environmental conditions. Given the limited favorable diurnal weather conditions available for ground searches during our study, capture rates of both gastropods and salamanders may have increased if searches were conducted at night when conditions were cooler and moister. However, safety concerns increase and animals are more difficult to detect during night searches (Heyer et al., 1994, p. 75–92).

Species representation of gastropods was similar for pitfall traps and ground searches; only two species were not captured by both methods (Table 3). The Pacific sideband snail (Monadenia fidelis fidelis) was absent from pitfall traps, whereas the banana slug (Ariolimax columbianus) was not encountered during ground searches. One could speculate that small gastropods, such as the Crater Lake tightcoil snail (Pristoloma arcticum crateris, <3 mm in diameter) may be overlooked when covering a sizable sample area (50 m²) in 30 min. However, given the relatively large size of the common banana slug, our failure to encounter it during ground searches suggests that a greater search effort was needed to ensure a complete species accounting.

Across the three stand conditions examined during our study, pitfall traps were consistently more efficient than ground searches for detecting salamanders (Table 4). The reverse was true for gastropods in general, and snails in particular. Both techniques were similarly efficient for capturing slugs in uncut stands, but ground searches were superior in clearcuts and commercial thins. These results suggest that stand conditions in our study did not alter the relative suitability of pitfalls and searches for capturing salamanders or gastropods.

Cover boards were largely ineffective at our southwestern Oregon sites (Table 2) despite no more than once per week sampling, as recommended by Marsh and Goicochea (2003). Because the boards and surfaces beneath them did not retain moisture, they appear to have provided limited protective habitat. Others studying salamanders have obtained similar results. Houze and Chandler (2002), for instance, found that $2 \cdot \times 30.4 \cdot \times 30.4 \cdot \times 30.4 \cdot \times 30.4$ cover boards were less effective at sampling terrestrial salamanders than ground searches in second-growth, mature pine (*Pinus* spp.) and oak (*Quercus* spp.) stands in Georgia. They proposed that greater daily temperature fluctuations occurred under boards compared with natural cover, making boards less desirable protective habitat. In southwest Virginia, Harpole and Haas (1999) found an average of 0.17 salamander per board in unharvested stands using $5 \cdot \times 30 \cdot \times 60 \cdot \times 60$

7/F								
	Clearcut	Thin	Uncut	All stands				
Salamander	1.65	1.21	1.81	1.54				
Gastropods	0.09	0.38	0.24	0.23				
Snails	0.07	0.38	0.20	0.20				
Slugs	0.20	0.34	1.03	0.42				

TABLE 4.—Proportion of pitfall to ground search captures on a per effort-hour basis in three stand types: clearcut, commercial thin and uncut

Vancouver Island in British Columbia (Davis, 1997), Maine (Monti et al., 2000) and Tennessee and North Carolina (Hyde and Simons, 2001).

Based on the results of our study, and those of others, we offer the following suggestions for improving the functionality of cover boards: (1) allow cover boards to season or decay slightly before monitoring, (2) check boards only during or immediately following suitable weather conditions (*i.e.*, rainfall), (3) construct cover boards from materials that retain moisture, (4) place boards directly on the ground without spacer sticks to inhibit desiccation of cover boards and (5) blanket boards with litter to help maintain moisture levels.

In summary, of the three sampling methods employed in southern Oregon Cascades forests, pitfall trapping was most effective for capturing salamanders based on total individuals and number of species encountered, despite the extensive setup time. Pitfall traps become more efficient the longer they are in use because of the decreasing contribution of installation time to the calculation of captures per overall effort. Ground searching and pitfall trapping both produced the same number of gastropod species, although ground searches were more efficient at capturing gastropods. Based on the limited numbers employed, cover boards in this study were largely ineffective for concealing either salamanders or gastropods, most likely as a consequence of the relatively dry conditions of the study units. A review of the literature suggests that effectiveness of various survey protocols for amphibians and gastropods is not consistent over large geographical areas.

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